'ARTMENT OF THE INTERIOR, CANADA
Hon. CHARLES STEWART, Minister; W. W. CORY, Deputy Minister

TOPOGRAPHICAL SURVEY OF CANADA
F. H. PETERS, Surveyor General

BULLETIN 45

THE TESTING OF THERMOMETERS AT THE PHYSICAL TESTING LABORATORY

OTTAWA
F. A. ACLAND
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
1925

CONTENTS

INTRODUCTORY NOTE

The increasing number of properties of materials, which it is becoming necessary to submit to accurate measurement in industry, emphasizes the necessity for the careful calibration of the instruments employed for the purpose against some fundamental standard. One of the important measurements to which these considerations apply is that of temperature. Until recently the lack of proper facilities for thermometer testing in Canada was such that scientific laboratories and others found it necessary to send their instruments to foreign countries if an independent calibration test of high order was required. The delays and other inconveniences consequent to this procedure may now be avoided as facilities for this work exist within the Dominion.

The thermometer section of the Physical Testing Laboratory has been developed and equipped with modern thermometric testing appliances for handling thermometers within the range —60° C. to + 300° C. With the aid of this apparatus complete tests may be conducted of commercial, laboratory, and other high precision thermometers and their corrections determined in terms of the standard scale of temperature.

THE TESTING OF THERMOMETERS

Standard Scale of Temperature

Determinations of temperature, if they are to be of value, must be referred to a standard unit or scale. Considerable difficulties were experienced in the early days of thermometric science owing to the defects of the temperature scales then in use. Later researches culminated in the thermodynamic scale of Lord Kelvin becoming the fundamental standard of reference to which all temperature determinations are referred. This scale is independent of the properties of any material substance. It is identical with the scale depending on the properties of a hypothetical " perfect " gas.

A " perfect " gas is defined as one which obeys Boyle's law, and one in which a free expansion, with no external work, would cause no change in temperature. In this gas, the expansion (which defines the temperature) whether under constant volume or pressure, would increase exactly in proportion to the quantity of heat required to produce it. A thermometer in which temperature changes were indicated by the alteration in volume or pressure of a perfect gas would measure accurately any temperature in terms of the unit adopted. In practice, the properties of the more permanent gases, within limits, are not widely different from those of the perfect gas, and the departures that exist can be accurately computed from the results of careful experimental research.

For the interval —30° to 100°C., the hydrogen thermometer reproduces the thermodynamic scale within limits of error smaller than the errors consequent to gas thermometer determinations. For higher temperatures, nitrogen and other gases may be used. The gas thermometer is not an instrument suited for ordinary temperature measurements, so that within the range 0° to 100°C., the scale is ordinarily preserved in carefully made and studied mercury thermometers, which have been directly compared with the hydrogen thermometer. For temperatures outside these limits, use is made of certain well defined and reproducible temperatures, such as the melting or boiling points of various substances, which have been determined directly in terms of the gas scale. A number of these temperatures* covering the range —250°C. to 1000°C. are known, the accuracy of the determinations being generally conceded.

*See Table I, Appendix.

The exhaustive experiments of Callendar and others have shown that a properly constructed platinum resistance thermometer (in which temperature changes are measured by the alteration of electrical resistance of platinum wire) when accurately calibrated at three temperatures on the gas scale will reproduce this scale to a high degree of accuracy. The platinum resistance thermometer is therefore becoming extensively used as the practical standard instrument for measuring temperatures on the gas scale in the interval –200°C. to 1100°C. This form of thermometer is also becoming widely employed for many scientific and commercial purposes for which mercury thermometers are less convenient, such as determining the temperature in the interior of ships' cargoes, of flue gases, etc.

THE MERCURY THERMOMETER

The "mercury in glass" thermometer is still by far the most widely employed instrument for measuring temperatures. Great difficulty was experienced by early workers when using the instrument in the course of the determination of important physical constants, due to the discrepancies between the indications of different thermometers and even between temperatures measured with the same thermometer. This thermometer has, therefore, been extensively studied by many investigators and the knowledge that has been obtained in their researches enables more accurate temperature determinations to be made with it. The main causes of the irregularities experienced by early workers were found to be:—

(*a*) Secular change in the zero.

(*b*) Variation in the value of the degree at different portions of the scale after correcting for volumetric calibration*, due to the irregular expansion of the glasses used.

(*c*) Zero depression, depending on the temperature to which the thermometer was exposed.

These errors were considerably reduced by constructing thermometers of special hard glasses, the best known being "verre dur" and the Jena glasses. The errors due to the use of these glasses are small and, moreover, being fairly constant, have been carefully determined so that the necessary corrections may be applied to thermometers made from a specified glass. These corrections, together with the constants determined for each thermometer, enable mercury thermometers, when the requisite refinements are introduced into the work, to measure temperatures to an accuracy of about .002°C. in the interval 0° to 100° C., the accuracy decreasing at higher temperatures, and becoming about 1° at 450° C. It is important where high grade work is required that the thermometers be constructed of a thermometric glass of proved quality and be thoroughly annealed after manufacture.

Testing of Mercury Thermometers

The following tests to mercury thermometers are made at the laboratory—

(1) Determination of the fundamental interval.

(*a*) Steam-point.

(*b*) Ice-point.

*Thermometers are now rarely calibrated by the volumetric method; the usual practice is to obtain the scale corrections directly by comparisons with a standard, as explained on page 7.

(2) Determination of internal and external pressure coefficients.
(3) Determination of corrections to the standard scale by bath comparators.

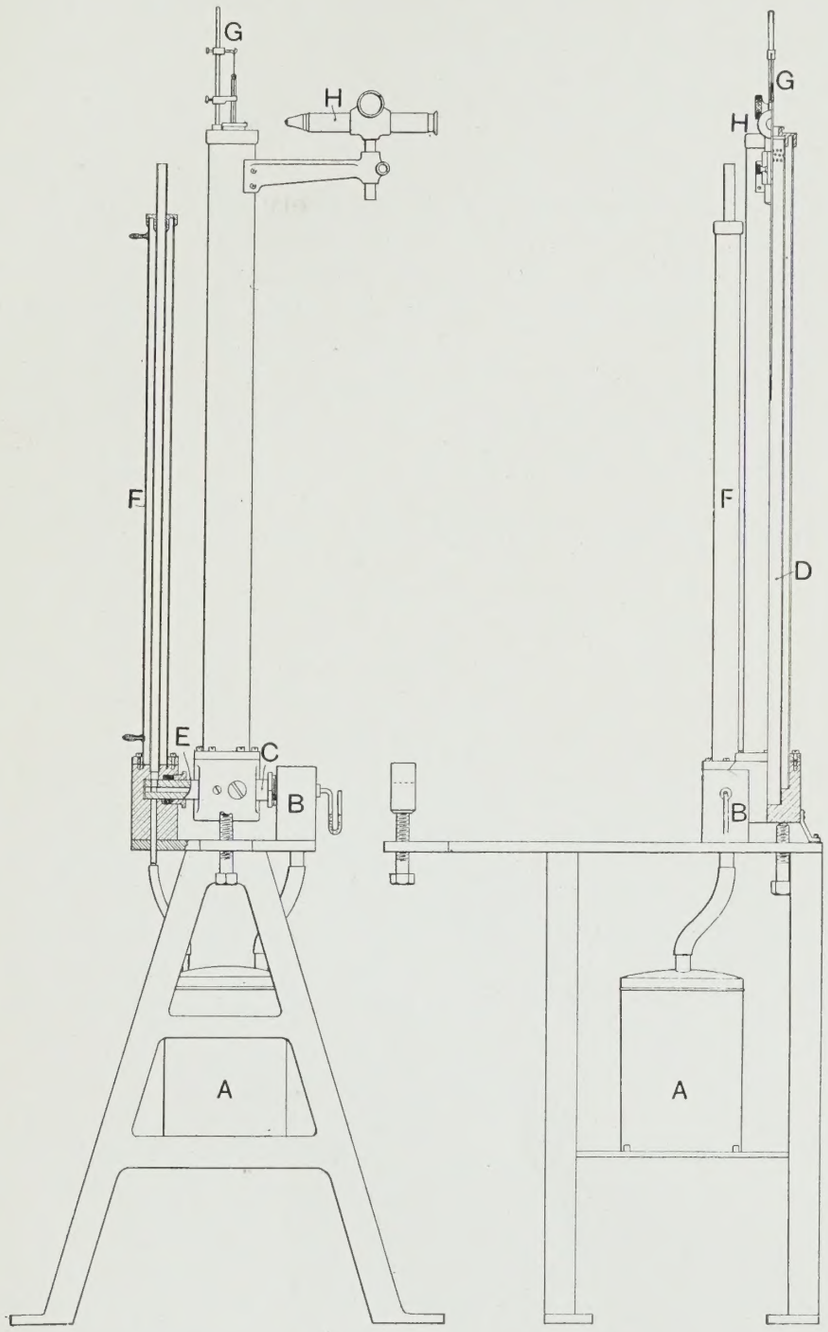

FIG. 1—Hypsometer

Determination of the Fundamental Interval

(*a*) *The steam-point.*—The correction at this point is determined by immersing the thermometer in steam in the apparatus shown in fig. 1. This apparatus is similar to the hypsometer employed at the International Bureau. The essential parts are a boiler *A* (containing distilled water), the steam from which rises through the trunnion box *B*, and thence through the trunnion *C* to the central tube *D*. The steam then flows down the annular space between the central and outer tubes through the trunnion *E* to the condenser *F*, the condensed water returning to the boiler. By supporting the steam jacket on trunnions, determinations may be made with the thermometer in either the vertical or horizontal position. The thermometer is supported by the holder *G*, the hole in the top of the steam chamber being covered by a thin rubber disc. The pressure within the apparatus is measured by a water manometer in communication with the hole in the trunnion *C*. The thermometer is read with the aid of the microscope *H*.

The steam point (100° C.) is the temperature of the vapour of distilled water, boiling at standard atmospheric pressure. A correction has to be applied to the observed steam point if the barometric pressure is different from the "standard atmospheric pressure," which is that of a column of mercury $760^{mm.}$ in height at 0° C., at latitude 45° sea-level. This correction is important, amounting to about 0.037° C. per $1^{mm.}$ of mercury.

(*b*) *The ice-point.*—The ice-point is determined as soon as possible after removal from the hypsometer, by inserting the thermometer in pure powdered melting ice. At the laboratory the ice is contained in an inverted bell jar, which can be drained at will. The jar is contained in a second larger jar, the annular space being packed with crushed ice. The whole is placed in a polished case.

To obtain a rising meniscus at the ice-point, the thermometer bulb is first cooled a few degrees below zero by inserting it in a bath of mercury, the container of which is immersed in a freezing mixture.

Determination of Internal and External Pressure Coefficients

In work of precision, corrections have to be applied to the observed readings due to the internal and external pressure effects. Although, if the thermometer is always used in the position in which it was originally calibrated, it is in general unnecessary to apply an internal pressure correction.

The internal pressure coefficient, usually denoted by *Bi*, is the coefficient which determines the difference between thermometer readings in the vertical and horizontal positions, due to the pressure exerted by the mercury column distending the bulb. *Bi* is defined as the change in reading in scale degrees caused by a change in pressure of $1^{mm.}$ of mercury within the thermometer bulb.

The external pressure coefficient *Be* is the change in reading in scale degrees due to a change in pressure of $1^{mm.}$ of mercury in the medium surrounding the thermometer. It can be shown that the relaton between these coefficients is given by:—

$$Be = Bi - 0.0000154$$

Knowing the dimensions of the thermometer, *Bi* can be determined directly from the difference in the steam point readings in the vertical and horizontal positions. In the case of thermometers which do not show the steam point, *Bi* is computed from the direct determination of *Be*, using the above formula. The apparatus used for the determination of *Be* is similar to that used at the International Bureau. The thermometer is immersed in water contained in a glass tube with sufficient mercury in the bottom to cover the bulb. The whole is contained in an outer vessel filled with water, the temperature of which is slowly rising. Readings of the thermometer are taken with the tube alternately in connection with the atmosphere and with an exhausted receiver. The external pressure coefficient is computed from the change in pressure and the corresponding difference in the thermometer readings.

Determination of Corrections to the Gas Scale by Bath Comparators

Primary standard mercury thermometers, i.e. thermometers bearing the fixed points 0° and 100° C. on their scales, were formerly calibrated by volumetrically subdividing the bore of the stem and so obtaining the correction at each degree in terms of the fundamental interval 0° to 100° C. Corrections to the gas scale were known if the thermometers were made of one of the standard glasses. However, all important laboratories are now in possession of standard thermometers which have been directly or indirectly compared with the gas thermometer, by which the normal hydrogen scale is preserved at the Inter-

national Bureau, Paris. For this reason the laborious process of calibration is now rarely performed. If a thermometer is constructed by a maker of repute, its corrections can be satisfactorily determined from comparisons made at a large number of points on the scale with a reliable standard in a bath comparator.

The Water-bath Comparator

The water-bath thermometer comparator of the laboratory is illustrated in fig. 2, while the construction may be seen in fig. 3.

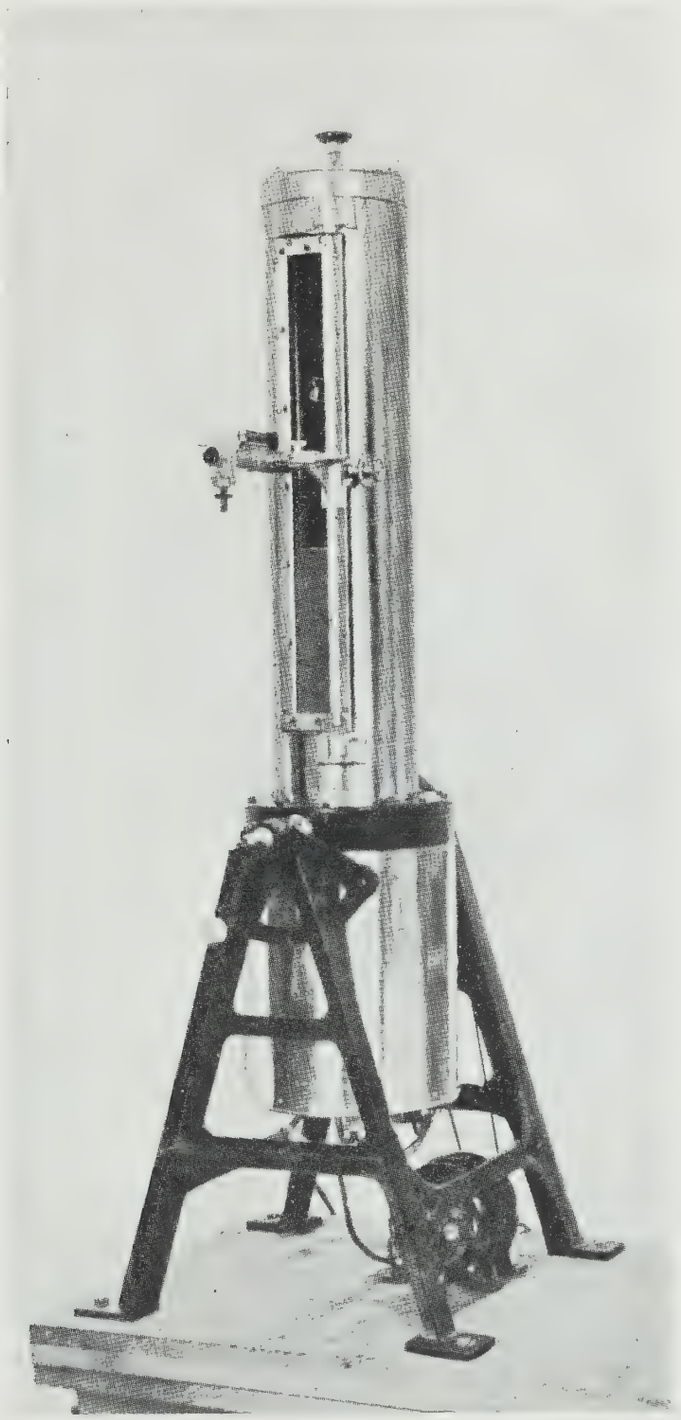

Fig 2.

The comparator consists of a body supported on trunnions *A*, carried in a supporting frame *B* and having a quadrant *C* with catch *D* so that the main body can be locked in either the vertical or horizontal position. Change from one position to the other can be quickly accomplished without disconnecting any part of the apparatus. The lower portion of the body contains the tem-

perature regulating and water circulating appliances. Hot or cold water can be circulated through the coil *E*, which is connected to the hollow trunnions.

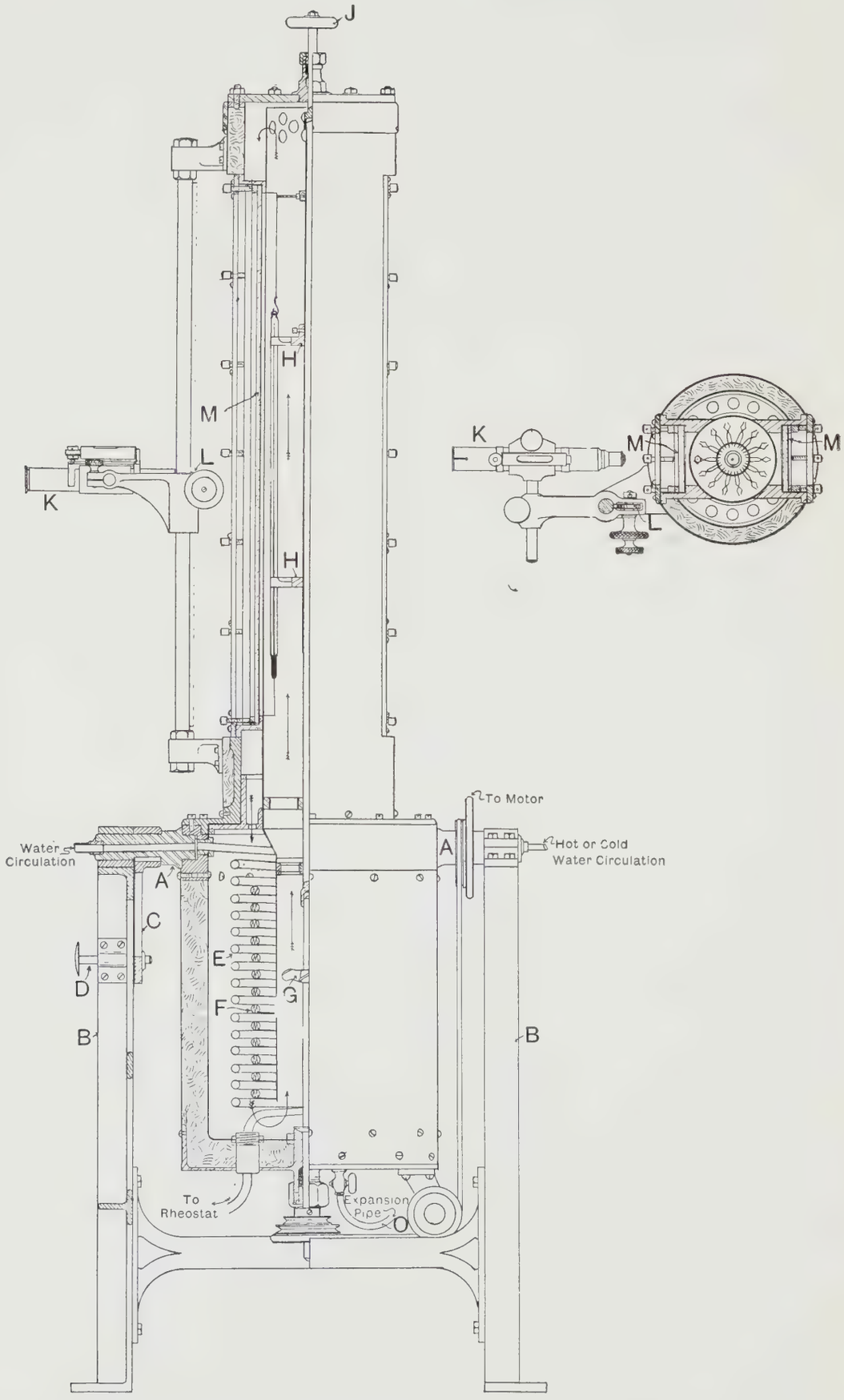

FIG. 3.—Diagram showing construction of water-bath comparator.

This water is used to change rapidly the temperature within the apparatus. The temperature can be accurately controlled by the aid of the resistance coil *F* in series with a rheostat which regulates the power from a few watts to 800

watts. A screw propeller *G*, driven by a system of belts and pulleys from a one-eighth horsepower motor, causes the water to circulate up the central tube

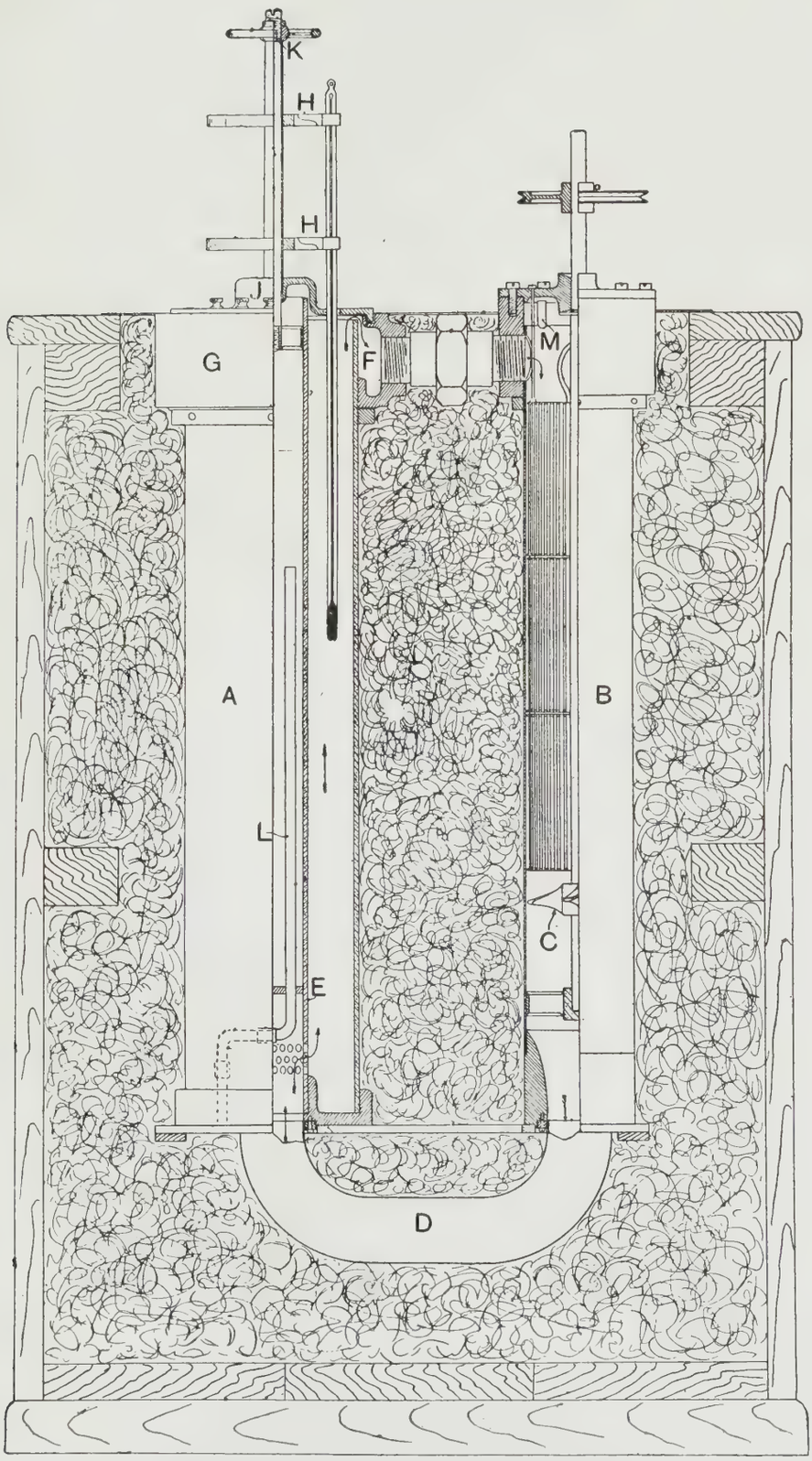

FIG. 4.—Oil-bath comparator.

and down again in the annular space, as indicated by the arrows. The thermometers being compared are supported in special carriers *H* with spring clips sufficient to hold fourteen thermometers. A wheel *J* enables the carrier to be rotated, bringing the thermometers in turn into the reading position, which is in line with the microscope *K*, adjustable in height by the rack and pinion *L*. The carrier for the thermometers may be removed from the comparator for loading. Long windows *M*, for illuminating and reading purposes, are let

into opposite sides of the upper portion of the comparator. Provision is made for preventing the pressure within the apparatus from increasing, due to the expansion of the confined water, by connecting a rubber tube *O* to the bottom of the comparator and leading the open end to a point just above the level of the top of the apparatus. The comparator is lagged to minimize the effects of change in room temperature. In making comparisons, the temperature is regulated so that the mercury meniscus is slowly rising. By bringing each thermometer into the same position in the bath for reading purposes, any error due to small differences in temperature at various portions of the bath is avoided. The efficiency of the circulating system and lagging is such, however, that the variations in temperature from point to point are extremely small, and may be considered negligible.

The Oil-bath Comparator

As a water bath is unsuitable for temperatures much over 90° C., corrections to the gas scale in the case of thermometers reading to about 300° C. may be determined by comparisons with standards in an oil bath. For the remaining portion of the range over which mercury thermometers are suitable, comparisons are usually made in baths of fused salts or other media.

The oil-bath comparator of this laboratory is shown in fig. 4. There are two cylinders, the larger one *A* containing the oil bath, while the second *B* encloses the heating and circulating units. The oil is caused to circulate by the belt driven propeller *C*, the path being downward through the pipe *D*, through the holes in the central tube *E*, past the thermometers, and over the open top of the outer tube into the annular space *F* in the top of the head *G*. Heating is accomplished by means of electrical heating coils, within the cylinder *B*, in which the current may be regulated so as to give the oil any desired temperature. The thermometers are held in the spring clips *H*, attached to the cover *J*. This cover is free to rotate, being supported by the adjustable pivot bearing *K*. The fumes are withdrawn from the bath by means of the tube *L* and from the heating chamber by the tube *M*. These tubes are conected to an exhausting pump, so that the interior of the apparatus is maintained at slightly below atmospheric pressure, preventing trouble due to excessive production of oil fumes. The comparator is enclosed in an outer wood casing packed with mineral wool.

The Use of Mercury Thermometers

When the mercury thermometer is employed for measuring temperatures to a high degree of precision, it is necessary that the user be familiar with the various errors to which the meaurements are liable.

Changes in Zero of Mercurial Thermometers

(*a*) *Secular rise in the zero.*—For some time after a mercury thermometer has been filled there is a gradual rise in the zero reading. If the thermometer is made of one of the standard glasses and has been carefully annealed by subjecting it to a high temperature for an extended period and gradually cooled, the slow rise of the zero can to a great extent be eliminated. In any case the change, which is probably due to the recovery of the glass from a state of strain produced during the manufacture of the thermometer, is likely to continue over some years and should be checked from time to time by determining the correction at the zero point. With mercury thermometers of approved glass, if the secular rise is checked by occasional observations, it may be assumed that the rise has taken place at a uniform rate between determinations. All readings at various portions of the scale of the thermometer should be corrected for this change in the zero.

(*b*) *Zero depression.*—If the zero correction is determined after the thermometer has been kept at a low temperature for some time, and again determined after being heated to a high temperature, it will be found that the zero is lower in the second instance. For work requiring great accuracy, errors due to zero depression and secular change in the zero are corrected by determining the zero immediately after each reading, and applying the correction determined. It is obvious, however, that in some cases, it is impossible to determine the ice point after each temperature measurement. In such cases, the zero depression corresponding to various parts of the scale can be determined from a table previously compiled by finding the ice point separately for each part of the scale. In applying corrections from such observations, which method is not so reliable as the direct method, care must be taken that the readings are not affected by the depression produced by recent heating to a higher temperature than that being measured, as it takes an appreciable time, generally some days at ordinary temperatures, for the depressions to disappear.

Correction for Emergent Stem

Scale corrections of thermometers are usually given for the condition of total immersion. If it is necessary that the thermometer be used with part of the stem and mercury column exposed to a hotter or colder medium than that surrounding the bulb, it is necessary that a stem correction be applied to the observed reading. This correction is important when the temperature difference between the bath and the medium surrounding the stem is large. In the case where a thermometer is employed with part of the stem exposed, a determination should be made of the mean temperature of the emergent mercury column by an auxiliary thermometer exposed near the stem of the main thermometer.

The stem corection may be computed from the formula:—

$$\text{Stem correction} = K\ N\ (t - t_o)$$

Where:—

K = Coefficient of relative expansion of mercury and glass.
N = Number of degrees of mercury column emergent from the bath.
t = Temperature of the bath.
t_o = Mean temperature of the emergent mercury column.

As illustrating the importance of this correction.—If $t = 160°$ C., $t_o = 50°$ C. and $N = 80$, the correction becomes $1.4°$ C.

Generally the correction calculated by this formula is not of great accuracy owing to the difficulty in obtaining an accurate value of the mean temperature of the emergent mercury column. It is only by employing special devices, which have been developed by various experimenters, that a reliable value can be obtained for this correction.

Correction for Lag

When a thermometer is immersed in any medium of constant temperature, it does not immediately indicate the true temperature. A certain time must elapse, depending on the type of thermometer, before the reading indicates the bath temperature. If the temperature of the bath is varying, the indications of the thermometer will lag behind the temperature of the bath. In the case of mercury thermometers, this correction is small and usually may be disregarded.

Application of Corrections

The certificate for a thermometer tested at the Physical Testing Laboratory will contain the values of one or more of the following:—

(1) Scale corrections at various temperatures in the horizontal and/or vertical position.
(2) External pressure coefficient.
(3) Internal pressure coefficient.

The external pressure correction is usually small unless the thermometer is at some depth below the surface of a liquid or exposed to a pressure much different from 760$^{mm.}$ of mercury.

The examples given show how the necessary corrections may be applied to the observed readings.

EXAMPLE

Tonnelot thermometer No. 38044.

(*a*) Vertical position—

Reading =20.070° C., external pressure at bulb =765$^{mm.}$
Ice-point + 0.038° C., external pressure at bulb =770$^{mm.}$

	Temp. to be measured	Ice-point
Thermometer reading	20.070	+0.038
Scale correction (vertical pos.)	— 0.060	.....
External pressure correction	— 0.001	—0.001
		+0.037
Ice-point correction	— 0.037	
Corrected temperature	19.972	

(*b*) Horizontal position—

Reading = 17.560° C., external pressure at bulb = 765$^{mm.}$
Ice-point (vertical position) +0.038° C external pressure at bulb = 770$^{mm.}$
Distance from centre of bulb to zero graduation = 69.8$^{mm.}$

	Temp. to be measured	Ice-point
Thermometer reading	17.560	+0.038
*Scale correction (horizontal pos.)	— 0.066	.....
External pressure correction	— 0.001	—0.001
Internal pressure correction	.....	+0.008
		+0.045
Ice-point correction	— 0.045	
Corrected temperature	17.448	

The foregoing deals but briefly with the more important errors of mercury thermometers; a complete treatment of the mercurial thermometer and an exhaustive discussion of the various errors may be found in Guillaume's " Traité Pratique de la Thermométrie de Précision."

CLINICAL THERMOMETERS

The testing of clinical thermometers requires additional apparatus to that needed for mercury thermometers of the chemical type. Clinical thermometers are relativly small and are generally received in large numbers for test. Moreover, owing to the low selling price, the test fee must be reasonable, necessitating rapid handling.

While clinical thermometers are sold for a small sum their accuracy is required to be of a relatively high order. In this connection it may be of interest to state that the National Physical Laboratory of England will only certify clinical thermometers constructed of approved thermometric glass to prevent the growth of errors subsequent to test. When it is considered that in some pathological work, particularly in tuberculosis cases, the accurate measurement of a

*If the scale corrections in the vertical position only are available, a correction has to be applied for the internal pressure effect.

patient's temperature is of the greatest importance, such regulations as these and other requirements for guaranteeing the accuracy of clinical thermometers are not unreasonable.

At the Physical Testing Laboratory the following tests are made to clinical thermometers:—

(*a*) General examination.
(*b*) Determination of scale corrections.
(*c*) Test for excessive constriction.
(*d*) Test for self registration of index.
(*e*) Test for difficulty of resetting index.

(*a*) *General examination.*—The thermometers are examined for cracks in the glass, air bubbles, detached mercury, or other mechanical defects. Thermometers are not certified when the graduations are imperfect, the numbering defective, or when any other faults exist which, in the opinion of the Laboratory officials, warrant rejection.

(*b*) *Determination of scale corrections.*—Scale corrections are determined in a water-bath comparator specially made for accommodating clinial thermometers. This bath holds 48 thermometers under test and two standard thermometers. It is shown diagrammatically in fig. 5 and is similar in principle to the oil-bath comparator, fig. 4.

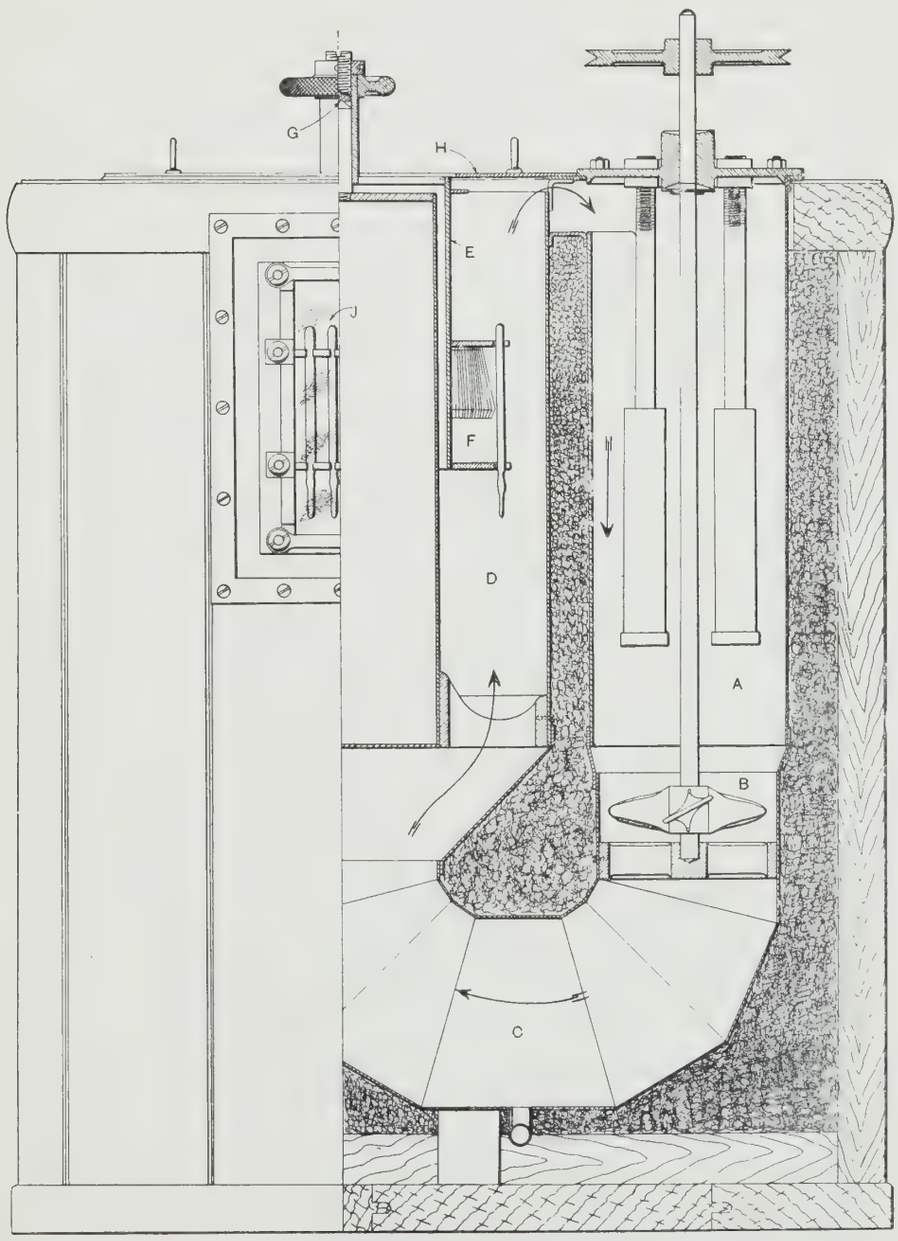

Fig. 5.—Water-bath comparator for testing clinical thermometers.

The cylinder *A*, to the right contains four electrical immersion heaters and the propeller *B*, belt driven from a small motor through a vertical shaft. The water is forced from the heating cylinder through the pipe *C* up into the annular space in the cylinder *D* containing the thermometers then over a lip into a chamber surrounding the top of *D* and so back to *A*. The circulation is rapid and a uniform temperature is maintained at any desired figure by regulating the switches controlling the heaters, which are wired in a series-parallel arrangement. The thermometer holder *E*, with spring clips *F* for holding the thermometers friction-tight in a series of holes in two parallel annular plates, rests on a pivot bearing *G*. For loading, the holder can be readily lifted from the comparator, after removing the cover *H*. Readings are taken with the thermometers completely immersed, through a plate glass window *J*.

Comparisons between the readings of the thermometers under test and the standards are made at the following temperatures, viz., 95·0°, 95·2°, 100·0°, 100·2°, 105·0°, 105·2°, 108·0°, and 108·2° F, in turn. When thermometers are graduated in the centrigrade scale, the test temperatures are 35·0°, 35·1°, 37·0°, 37·1°, 39·0°, 39·1°, 42·0°, and 42·1° C.

(*c*) *Excessive constriction.*—Excessive constriction will show itself, during the test just treated, by a relative difference in the scale corrections at the test points one-fifth of a degree apart or by other irregularities during the test. Great skill is required in making the constriction in a clinical thermometer sufficiently effective to trap the mercury when the temperature drops, and yet free enough to allow the column to rise easily. If a clinical thermometer is watched under a uniformly increasing temperature the index will be seen to rise by a series of jumps. In the case of a badly made thermometer the jumps are large and erratic and the thermometer cannot, naturally, be considered reliable.

(*d*) *Registration of index.*—While the constriction in a clinical thermometer must be free enough to permit the mercury to rise without restraint and to allow the index to be readily reset, it should also be of such form that the index will not retreat when the thermometer is removed from a higher to a lower temperature, as when a patient's temperature is observed. This tendency is tested by allowing the temperature of the comparator to fall quickly after the thermometers have been read at the highest temperature of test. A reading of the clinical thermometers taken subsequent to the temperature drop should give the same indication as the previous reading at the high temperature. Thermometers showing a drop greater than 0·2° F. or 0·1° C. are rejected.

(*e*) *Resetting.*—Usually a "hard shaker" will reveal itself by irregularities in the scale corrections, as the defect is generally due to excessive constriction. It may be detected positively however in the centrifuge employed to set the thermometers at the commencement of the test. If the index of any thermometer will not retreat at a centrifuge speed corresponding to normal shaking by hand, the thermometer is rejected.

Certificate.—Each thermometer found to have a scale error not exceeding 0·2° F. for temperatures below 106° F., or 0·3° F. for higher temperatures, and which otherwise satisfies the test requirements, is etched with the letters P.T.L. Official certificates are also issued giving the scale corrections for the temperatures 95°, 100°, 105°, and 108° in the case of every thermometer passing the test.

THE PLATINUM RESISTANCE THERMOMETER

Resistance thermometers depend upon the variation of electrical resistance of metal wire with temperature. Platinum is used in most cases, and has the advantage of giving a regular resistance-temperature curve over a large range. If properly constructed and intelligently used, platinum resistance thermometers

will measure temperature with great accuracy over the range —200° C. to 1000° C. This thermometer is also able to measure small changes of temperature with a degree of accuracy far greater than that possible in mercurial thermometry. The usual pattern of resistance theremometer consists of a coil of platinum wire wound on a mica rack and enclosed in an outer tube constructed of porcelain, quartz, or other material depending on the class of work for which the thermometer is intended. The resistance is measured by means of a resistance bridge and galvanometer. Errors due to change of resistance of the leads with temperature are compensated by providing a duplicate set which are in series with the opposite arms of the bridge.

Callendar introduced the following nomenclature:—

The platinum temperature pt is defined as:—

$$pt = 100\,\frac{Rt - Ro}{R^1 - Ro}$$

Where Ro = resistance at 0° C.
R^1 = resistance at 100° C.
Rt = resistance at t° C.

The difference between the quantities t and pt was shown to be—

$$t - pt = d = \delta\left\{\left\{\frac{t}{100}\right\}^2 - \frac{t}{100}\right\}$$

where δ is a constant for a particular thermometer. The value of δ is determined for each thermometer by standardizing at three temperatures, usually 0° C., 100° C., and 444.5° C. (the boiling point of sulphur). From these determinations the value of the corrections to convert platinum temperatures into temperatures on the standard scale are computed.

The platinum resistance thermometer, besides giving greater accuracy over a wider range than the mercurial, does not suffer from zero depression; the ordinary pattern, however, has a greater lag. The platinum thermometer besides being extensively used for precision work, is also employed for industrial purposes. For obtaining temperatures over the range 0° to 1100° C. in the latter case, a special self-contained direct reading resistance balance is employed, which enables unskilled observers to obtain quickly temperatures to an accuracy of about 1/3° C.

APPENDIX

TABLE I

Standard Temperatures on the Thermodynamic Scale as given by the freezing or boiling points of various substances.

Substance		Temperature
Hydrogen	(boiling)	−252·7° C.
Oxygen	(boiling)	−182·9
Mercury	(freezing)	− 38·88
Tin	(freezing)	231·84
Benzophenone	(boiling)	305·9
Zinc	(freezing)	419·4
Sulphur	(boiling)	444·5
Antimony	(freezing)	630
Salt	(freezing)	801
Sodium Sulphate	(freezing)	883·2
Silver	(freezing)	961
Gold	(freezing)	1063

BULLETINS ISSUED

By the Physical Testing Laboratory of the Topographical Survey of Canada

Department of the Interior

41. Tests of Small Telescopes at the Laboratory of the Dominion Lands Surveys.
42. The Testing of Aneroid Barometers at the Physical Testing Laboratory.
43. The Testing of Timepieces at the Laboratory of the Dominion Lands Surveys.
44. Standardization of Measures of Length at the Laboratory of the Dominion Lands Surveys.
45. The Testing of Thermometers at the Physical Testing Laboratory.
48. The Adjustment and Testing of Transit Theodolites, Levels and Surveying Cameras at the Laboratory of the Dominion Lands Surveys.